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Strengthening of RCC Column Using Glass Fibre Reinforced Polymer (GFRP)

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Abstract

The application of composite materials has been developed in strengthening and retrofitting of concrete structures through recent years, so that many of concrete structures would be strengthened by these materials. One of these applications are Glass Fibre Reinforced Polymer (GFRP) material used in strengthening and retrofitting of reinforced concrete columns. Results of studies have shown that wrapping of reinforced concrete columns with GFRP caused increasing of ductility and compressive strength of Reinforced Cement Concrete(RCC) columns. Since, almost all RCC columns are affected by axial force and moment bending. Studies of interaction curve of wrapped RCC columns with GFRP shows that just compressive control region in interaction curve enhance and wrapping of columns with GFRP has no affected on tension control region of RCC columns. The objective of this research work is to enhancement axial compressive strength of RCC columns retrofitted by GFRP system that oriented in the direction of applied axial load. The reinforced concrete columns designed and modeled under axial load. It is demonstrated analytically that it is possible to strengthen the compressive strength of RCC columns with GFRP.

Keywords: GFRP, Compressive strength, Ductility, Axial load, flexural strength

INTRODUCTION

Concrete is one of the most versatile construction materials. The same is now being used in all types of Civil Engineering structures. Its flexibility in giving desired shape (like folded plate, shell etc), economy and other features made it as one of the preferred building materials. Result is that, now most of the Civil Engineering structures are made of concrete.

During the initial stage, it was thought that concrete will be a maintenance free structure. Later on, this myth has proved wrong. Due to majority of Civil Engineering structures being RCC and on account of its requirement of maintenance, quantum of such strengthening work has also increased tremendously.

There are so many strengthening procedures. Strengthening with the help of GFRP is one of them. This is a new technique having tremendous potential. This paper deals the strengthening procedure of RCC column with the help of GFRP has been discussed.

Muhammad and Shamim[1] (2005) investigated the effectiveness of GFRP wraps in strengthening and repairing of damaged square concrete columns. Concluded square concrete columns externally retrofitted by GFRP wraps and tested under axial compression and cyclic loading, simulating seismic loads, showed pronounced un retrofitted columns. Higher ductility and improved seismic performance can be achieved by retrofitting damaged square concrete columns with GFRP jackets. Kumutha[2] et al (2007) evaluated the effectiveness of external GFRP strengthening for rectangular concrete columns to calculate the effect of number of GFRP layers on the ultimate load and ductility of confined concrete. Effective confinement using GFRP sheets resulted in improving the compressive strength. Better confinement was achieved when the number of layers of GFRP wrap was increased, resulting in enhanced load carrying capacity of the column, in addition to the improvement of the ductility.

Nagaradjane[3] et al (2007) done an experiment on the plain concrete cylinders of 150mm diameter that was cast using M30 grade concrete out of which five specimens were wrapped with GFRP and it was found that the increment in strength due to the application of GFRP wraps ranged from 39.49% to 56.20%. Strengthening of Compression member using GFRP wraps contributed very much to the increase in load carrying capacity of columns. GFRP wrapping resulted in increase of axial strain capacity from 93.33% to 412.33% and lateral strain capacity from 785.68% to 1442.42%.Compared to the control specimen, GFRP confined specimen exhibited higher axial and lateral strains at ultimate condition and lower axial and lateral strains before failure. The application of GFRP confinement contributed to the increase in compressive strength as well as ultimate strain levels in the specimens.

Cui and Sheikh[4] (2010) conducted an experiment on wrapped columns and concluded that, strength enhancement effectiveness appears to be independent of the amount of FRP when high modulus FRP is applied. There is a minimum amount of FRP required to achieve strength enhancement. This minimum requirement increases with unconfined concrete strength and decreases with stiffness of FRP. Energy absorption capacity of the specimens increased proportionally with the number of FRP layers and was more pronounced for lower strength concrete.

Antonio De Luca and Antonio Nanni[5] (2011) evaluated the single parameter methodology for the prediction of the stress-strain behaviour of FRP confined RC square columns and concluded that, transverse/ diagonal dilation ratio -axial strain curves are influenced not only by the modulus of elasticity and the thickness of the jacket but also by the fibre type. However, it is believed that the validity of the theoretical framework is independent from the fibre type.

Houssam[6] et al. have investigated the behaviour of large-scale rectangular columns and found that the higher aspect ratio resulted in a reduction in the confinement pressure and the compressive strength of a confined column increased as the corner radius increased. Lau and Zhou[7] studied the behaviour of FRP wrapped concrete cylinders with different wrapping materials and bonding dimensions by using the finite element method (FEM) and other analytical methods.

Manuel and Carios[8] have done tests on models of circular cylindrical columns of concrete with GFRP jackets subjected to axial loading for different heights of cylinders and it was found that the increase in number of layers led to an increase in the maximum load. Riad et al.[9] have investigated on square prismatic concrete column strengthened with external glass fibre composite. It was found that the stiffness of the applied FRP jacket was the key parameter in the design of external jacket retrofits.

Shamim et al [10] have studied the seismic behaviour of concrete columns confined with steel and FRP. It was concluded that the use of FRP significantly enhances strength, ductility, and energy absorption capacity of columns. Zhao and Feng[12] (2003), investigated experimentally the seismic strengthening of RC columns with wrapped CFRP sheets. The ductility enhancement with the confinement of CFRP sheets was studied by the strain development and distribution in the CFRP sheets.

Richard D. lacobucci et al[11] (2003) done an investigation on retrofit of square concrete columns with Carbon Fibre Reinforced Polymer (CFRP) for seismic resistance. It was found that added confinement with CFRP at critical locations enhanced ductility, energy dissipation capacity and strength of all substandard members.

MATERIALS USED

A. *Cement*

Ordinary Portland cement 43 grade is used for design mix. The fineness modulus of cement is 5% and the specific gravity of cement is 3.15.

B. *Aggregates*

Size of coarse aggregate is 20mm, Specific gravity is 2.6, Water absorption is 0.5%. Specific gravity of fine aggregate is 2.6, water absorption is 1%, free surface moisture is 2%

C. *Water*

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Water cement ratio is 0.49.

D. *Steel*

Used Fe 456 Grade steel tested in UTM. 12mm bars were used for longitudinal reinforcement and 8mm bars used as transverse reinforcement.

E. *GFRP*

a) ***Characteristics*** Uniform fibre distribution, smooth surface, soft and pliable feel, Low binder and strainer content, fast resin impregnation and good mould obedience.

b) ***Specifications*** Weight: 30 g/m^2, Binder content: 7%, Resin wet out time: 10 s, Tensile strength: 20N/5cm, Moisture content: 2% maximum Width: 1 m.

F. *GP Resin*

General Purpose Orthopthalic Polyester Grade - PX GP 002. Its characteristics are clear to light, Yellow, Medium reactivity, High impact and bonding Strengths Suitable for hand lay-up.

EXPERIMENTAL WORK

A. *Specimen Preparation*

The test program consisted of casting and testing of nine columns. All the nine columns having a size of 800 mm x 150 mm x 150 mm using M20 grade of concrete and Fe 456 grade steel. Each column was reinforced with four 12 mm diameter steel bars for longitudinal reinforcement and 8mm diameter bar for transverse reinforcement. Three control columns designated as CC-1, CC-2 and CC-3 as shown in figure 2 and three columns strengthened with single layers of GFRP are designated as SC-1, SC-2 and SC-3 as shown in figure 4. Three columns strengthened with double layer of GFRP are designated as DC-1, DC-2 and DC-3 as shown in figure 5.

The bonding surface of the GFRP sheet as shown in figure 1was cleaned with acetone.

Figure 1. GFRP Sheet

Three chemical were used to prepared epoxy resin.

Epoxy = 1000ml, Polyurethane coating = 20ml

Vinylester = 20ml.The mixed epoxy resin was applied uniformly over the concrete surface. After applying resin coat, the GFRP sheet was wrapped over the specimen shown in Figure 3. The specimens were allowed to dry for seven days under natural atmosphere conditions

Figure 2. Control Columns

Figure 3. Wrapping of GFRP mat in Column

Figure 4. Single layered GFRP wrapped Columns

Figure 5. Double layered GFRP wrapped Columns

B. *Testing Programme*

The columns were tested using UTM of 100 tonnes capacity. Axial compressive load was applied on the column up to failure as shown in figure 6. Ultimate compressive load and corresponding deflections were recorded as shown in figure 7. Figure 8 shows crack pattern in control column. Failure of GFRP wrapped column is shown in figure 9.

Figure 6. Axial Compressive load on Control Column

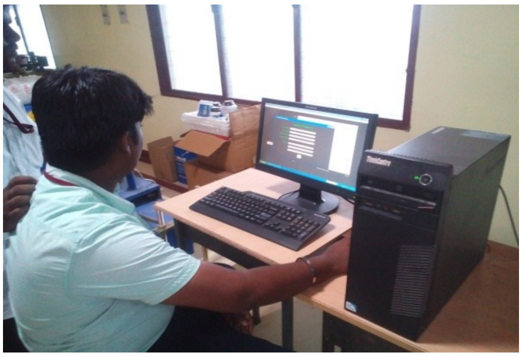

Figure 7. Results Obtained from UTM

Figure 8. Crack pattern in Control Columns

Figure 9. Failure of Single layered GFRP Wrapped Column

EXPERIMENTAL RESULT

Failure load, peak deflection, stress and strain for control column, single layered GFRP wrapped column and double layered GFRP wrapped column were listed in Table 1.

Table 1: Test Results

Description of Column	Failure Load (kN)	Peak Deflection (mm)	Stress (N/mm^2)	Strain	Increase in Compressive Strength (%)
CC-1	192	16.2	8.533	0.0231	
CC-2	178	15.3	7.911	0.0219	
CC-3	185	17.2	8.222	0.0246	
SC-1	220	8.1	9.778	0.0116	
SC-2	208	7.4	9.244	0.0106	15.31
SC-3	212	7.1	9.422	0.0101	
DC-1	252	5.9	11.200	0.0084	
DC-2	234	5.2	10.400	0.0074	31.35
DC-3	243	6.1	10.800	0.0087	

LOAD VERSUS DEFLECTION GRAPHS

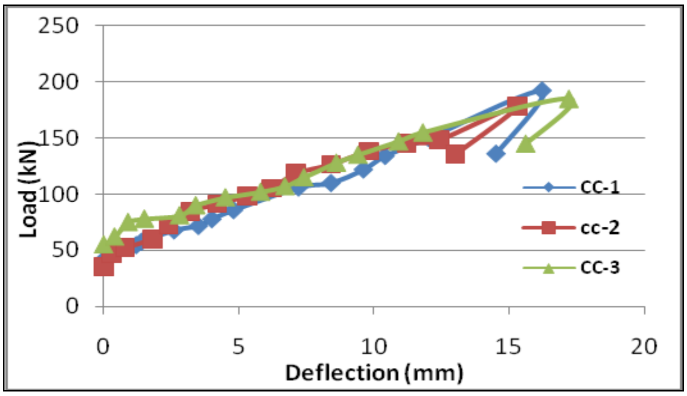

Figure 10. Load Vs Deflection for Control Columns

Load versus deflection curve were drawn for three control specimen (CC-1, CC-2 and CC-3) were shown in figure 10. The peak deflection is varied from 15.3 mm to 17.2 mm and the corresponding failure load varies between 178 kN and 192 kN. Among these three specimens, the minimum peak deflection was 15.3 mm recorded for CC-3 and corresponding load was 178 kN.

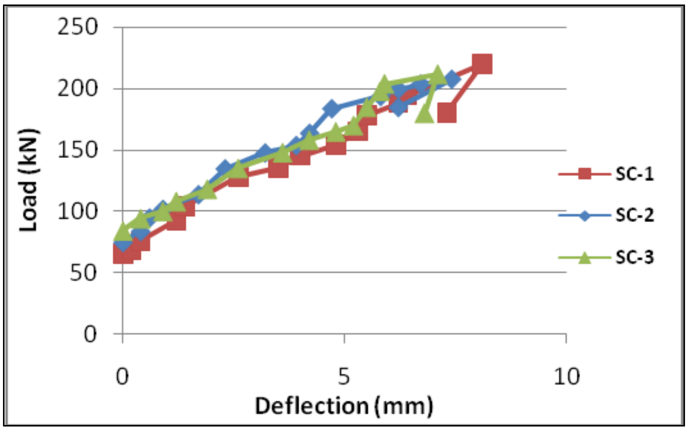

Figure 11. Load Vs Deflection for Single Layered GFRP Wrapped Columns

Figure 11 shows the load vs deflection curve pattern for single layered GFRP specimen SC-1, SC-2 and SC-3. The minimum peak deflection is recorded as 7.1 mm in specimen SC-3 and the corresponding failure load was 212 kN. The peak deflection is varied between 7.1 mm and 8.1 mm and the corresponding failure load varied between 208 kN and 220 kN.

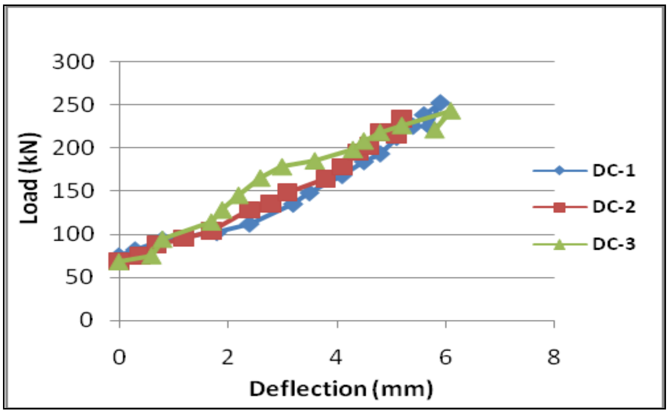

Figure 12. Load Vs Deflection for Double Layered GFRP Wrapped Columns

Pattern of load vs deflection curve for double layered GFRP column (DC-1, DC-2 and DC-3) were shown in Figure 12. Among these three specimens a minimum deflection of 5.2 mm is recorded in specimen DC-2 and the corresponding load was 234 kN. The peak deflection varied between 5.2 mm to 6.1 mm and the corresponding failure load were varied between 234 kN and 252 kn.

CONCLUSIONS

Nine Columns designated as CC-1, CC-2, CC-3, SC-1, SC-2, SC-3, DC-1, DC-2 and DC-3 were tested for axial compressive loading using UTM. Comparative study was carried out between control column and strengthened columns (SC and DC) with different layouts of GFRP mats.

Based on experimental results, the following conclusions are made

- The axial compressive strength of RCC column wrapped with single layered GFRP is increased by 15.31% compared to control column.
- Increase of axial compressive strength in double layered GFRP wrapped column is 31.35% compare with control column.
- The percentage decrease of deflection in single layered GFRP wrapped column is 53.5% and double layered GFRP wrapped column is 64.68% compared to control column.

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